Title:

‘Digital Dancing’ – “Can you see, what I feel”

– An exploration of the physical ‘experience’ of dance for Parkinson’s through 3-dimensional motion analysis.

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Abstract:

Background:

Parkinson's is a common, progressive, neurodegenerative movement disorder of the central nervous system. Research has consistently shown that dancing can have a positive impact on the lives of people living with Parkinson's (PwP).

PwP who dance report that current measurement of the effects fails to appreciate the multifactorial presentation of the condition as well as the biopsychosocial potential of dance holistically.

Aim:

To explore the feasibility of combining measurements of whole-body movement using 3-dimensional motion analysis with the lived experience of dance for PwP, to see if it is possible to 'see (measure)' what PwP say they 'feel (experience)' when dancing, in a 'mind/body approach'

Method:

Thirteen PwP and ten Carers took part in three community delivered 'Parkinson's Dance Science' classes followed by focus group reflection. Three PwP wore a 3-dimensional, motion capture suit that recorded whole-body movement throughout the class and were interviewed about their experiences.

Data were analysed using a 'Convergent Parallel' mixed methods design, mapping participant's experiences and reflections over six biomechanical movement variables.

Results:

Quantitative results indicate that it is possible to use 3-dimensional motion capture to measure biomechanical change during and following dance in PwP but the amount and direction of change was different for each participant.

Qualitative results showed PwP felt the methods were feasible and reported a positive immediate and long-term effect of dance in a complete 'mind/body experience'.

The sample size did not permit further analysis, but areas of development suggest it may not be the change in physical ability that is important, but more the perception of change following dance that is unique to each individual. Thus single measures of the effects of dance for PwP are likely to be insufficient when trying to understand the effect holistically.

Conclusion:

A 'Convergent Parallel' mixed methods research design, mapping the experience of dance for PwP ('what I feel') and their peers against biomechanical change ('what you see') following dance is feasible.

Further research is required to develop the method with a larger sample to truly begin to understand the potential and effects of dance for PwP.

Introduction:

Parkinson's is a common, progressive, neurodegenerative movement disorder of the central nervous system, presenting with particular impairment of the motor systems as well as the autonomic nervous system and state of mind. It is estimated to affect one in 500 of the population in the United Kingdom, totalling an estimated 137,000 and whilst prevalence increases with age, 1 in 20 who present with the condition are under the age of 40 [1]. The condition is varied and multi-dimensional, demonstrating a broad spectrum of symptoms with no two people living with Parkinson's experiencing the same combination of symptoms, and symptoms changing and evolving, for each individual across the course of the disease.

Research has consistently shown that dancing can have a positive impact on the lives of those living with Parkinson's. High level evidence has shown improvements in both the motor and non-motor symptoms associated with the condition [2, 3]. Specifically, systematic review and meta-analysis has shown positive impact of dance on quantitative, clinical measures of disease severity [4], balance [3, 5-7], gait endurance and speed (stride length) [3, 5-8], upper limb function, falls [7, 9], cognitive function, activity participation and fatigue [5] when compared to no intervention in PwP. When considering the effects of dance on more specific measures of biomechanical movement, Hulbert et al [10] used 3- D motion analysis in a gait laboratory, in a pre-post experimental design to show a positive effect on the coordination of head and pelvis rotation during turning following 10 weeks of twice weekly ballroom dancing. Using a similar static motion capture system, Sowalsky et al. [7] showed improvements in gait and balance parameters following 16 weeks of dance in a case study with Parkinson's.

It is therefore widely accepted that dance has a positive physical effect on those living with Parkinson's, however all studies to date have used measurements that are not dance specific and in doing so reduce the complexity of measurement down to single, isolated variable or standardised outcome measure. Dance in its nature is a complex, multidimensional activity and therefore single measurements are unlikely to capture the true, personalised, whole-body and mind effect, or the impact on the sequential and combined body movements of everyday living. There is widespread recognition that dance is more than just therapy, allowing a means of creative expression and enables people to immerse themselves in the art-form rather than focusing on the condition [11]. The holistic potential of dance is repeatedly reported through positive effects on quality of life in those with Parkinson's following dance [12-18]. It has been demonstrated as enjoyable, mood enhancing [17, 19] and decreasing clinical symptoms of anxiety and depression [16]. Alongside this, classes are socially engaging [15], increasing motivation to start and maintain physical activities and exercise [20] and improve cognition [17], all of which consequentiallly improve health-related quality of life [21], and fundamentally, long-term condition management.

Whilst qualitative enquiry goes some way towards understanding the positive lived experience of participating in dance classes, it is unclear what may be driving these experiences and the impact the physicality of dance has in generating them. Collectively, current literature highlights some of the multidimensional qualities of dance for PwP using a variety of measures, but once again these are universal measures used for all participants, so it does not allow for an appreciation of the varied and diverse effect that the artistic experience of dance may have for each individual. PwP who dance report that this fails to appreciate the multifactorial presentation of Parkinson's and the varied effect it has between individuals and within individuals on a day by day basis. It also simplifies the complex and unique affect that dance can have on both the mind and body and indeed the combination and interaction of the two in each individual. For some PwP, dance brings improvements in physical symptoms, but for others the connection with others in the room and the emotional feeling is more important. Many describe experiences of 'moving more freely', 'feeling looser', 'feeling less isolated' and 'escaping the condition', stating these as the main reason to dance (anecdotal feedback from dance classes for PwP).

This study aimed to address these concerns by combining measurements of whole-body movement in a complete dance sequence and linking this to the lived experience reported by someone living with Parkinson's when they dance. In doing so, the aim is to investigate if it is truly possible to 'see (measure)' what people say they 'feel (experience)' when dancing in both a complete mind and body experience. Only then will we truly begin to understand the unique effect dance has to offer PwP.

Method:

Study design

This was a mixed method, explorative study to investigate the physical 'experience' of dance for PwP through both quantitative methods of movement analysis and qualitative methods of semi-structured interviews and focus group discussion. Members of a well-established community dance class for PwP were consulted and contributed to the design of this study suggesting two objectives:

1. Is it feasible to collect measurements of movement in the whole-body in someone with Parkinson's dancing and their experience of the effect of the dance at the same time?
2. Are there any links between what PwP say they 'feel' when they dance and what movements can be measured/'seen'?

Setting

Participants were invited to attend a 60 minute, Parkinson's community dance class taught by two experienced teachers in a dance studio at Pavilion Dance South West, Dorset, UK on one day.

The class followed the Parkinson's Dance Science approach to teaching dance to PwP. The approach was co-designed by a Specialist Physiotherapist and Dance Artist. It aims to provide a 'Personal, social, artistic and creative dance experience with a theoretical, evidenced and therapeutic underpinning'.

Participants

Participants already attending Parkinson's Dance classes were invited to take part. Inclusion criteria included; a confirmed diagnosis of Parkinson's; able to tolerate up to 90 minutes of dance activity (which could be seated); be able to follow instructions and give informed consent. Participants' carers were also invited to attend the class. Three participants with Parkinson's participated in the quantitative data collection and all class members with Parkinson's and carers participated in the qualitative data collection.

Data collection

Informed, written consent (carers and PwP) and demographic data (including Hoehn and Yahr scale)[22] (PwP only) was collected prior to participants and their carer's being allocated to one of three dance classes.

The focus of the class in this research was on creativity and fun based on a theme of Spanish Flamenco. An appreciation of the physiological symptoms of Parkinson's and the impact of rehabilitation underpinned each exercise. Exercises included a seated posture and fun whole-body warm up, striding and gait education, lower limb strengthening, foot and ankle mobility, trunk rotation and posture whilst using the ballet barres, creative exploration and a cool down.

Purposive sampling, based on disease severity enabled the selection of one participant per class (Hoehn and Yahr scale, 1, 2 and 3)[22] to wear a 3-dimensional motion capture suit (as there was only one suit available for testing). The suit included 32 motion sensors in a lightweight headband, gloves, waist belt, shoulder strap and leg straps. The modular system is based on the NEURON, an Inertial Measurement Unit composed of a 3-axis Gyroscope, 3-

axis accelerometer and a 3-axis Magnetometer. This creates a 9-axis sensor unit that transmits data to a remote hub via wifi or can be recorded in internal or external storage. The suit is portable, and can be used in a range of environments outside of a traditional biomechanics lab.

Prior to and following the class, the selected participant learnt and performed a set dance phrase. This included specific movements that are typically affected by Parkinson's and therefore addressed under the physiological underpinnings of the Parkinson's Dance Science approach, whilst wearing the suit. Movements included trunk rotation, arm swing, walking, whole-body extension and postural correction, linked together in a fluid dance sequence. Three repetitions of this dance sequence were recorded using the motion capture software provided with the suit, converting the 3-dimensional data into a 'real time' avatar. Following the class, a 30-minute, post-class interview was conducted with the selected participant. In-depth interview skills were used to openly explore experiences of the class and any potential effects (physical, psychological or social). The final phase of data collection included a sharing of the pre and post digital 3-dimensional avatar recordings of the dance sequence with the entire class. Comparisons were discussed in a focus group format.

Interviews and focus groups were recorded and later transcribed verbatim for analysis. All data were anonymised for analysis, identifiable only by participant ID number.

Quantitative data:

Using the Mocap analysis software, the following variables were extracted from the pre- and post-dance sequence recordings. Each variable was created from a combination of sensor points and over a set period of time during the sequence. This enabled a combination of body movements and the flow of movement to be captured for whole dance movements. The research team had previous experience of using the Mocap System for observing and measuring dance and from a pragmatic perspective; it was available for use in this feasibility study without additional training. Due to limited time with the participant on location, the team decided to use a standard set of calibrations and settings for the Mocap system. This provided a normalised motion capture across the three participants in this study which allowed the team to increase the repeatability of the experiment – previous experience with the MoCap has found the MoCap system used to produce data with enough accuracy to test the viability of such a study.

Table 1: List and description of Quantitative variables extracted from the 3-dimensionalimensional Motion Analysis.

Variable	Sensors used	Movements analysed
Velocity of upper limb movements	Combined shoulder, upper arm, forearm and wrist	Looping figure of eight overhead arm swings right and left.
Rotation of the trunk	Horizontal axis drawn between shoulder markers and between lateral hip markers. Maximum	The maximum difference seen between the two axis in the looping arm sequence (as above)

	difference between two axis taken as rotation	
Gait analysis x 2 (speed, step length, over a 2 metre distance)	Speed - Velocity of the right ankle marker.	Average of the 2 steps in the walking section (out of 4 taken R/L/R/L).
	Step length - distance travelled of right ankle marker over ground	Average of the 2 steps in the walking section
Postural alignment	Horizontal axis drawn between shoulder markers and between lateral hip markers. Maximum difference between two axis taken as anterior/ posterior difference	One off measure at a moment of stillness following looping arm sequence.
Whole-body extension (width and height)	Horizontal axis drawn between shoulder markers and between lateral hip markers. Maximum difference between two axis taken as anterior/ posterior difference	Greatest difference reached following the looping arms section. Greatest height reached with arms over whole period. Greatest width reached with arms over whole period

The data were extracted by loading the recorded sessions as FBX motion capture files into the Unity game engine and then played back on standardised humanoid rigged game character (Unity's Robot Kyle asset). "virtual accelerometers" (custom Unity C# code) were attached to points on the game character's skeleton, which were connected to Node-RED (backend software which allows other software to be connected together) and exported the required data from each of the points on the body into separated 'Comma Separated Values' files. This normalised the movement as game engine units – approximately 1m to 1 unit. For each virtual accelerometer we exported the position of the point in 3D space (an X, Y and Z co-ordinate in game engine units) and the rotation of the point in three directions (pitch, yaw and roll – translated as Alpha, Beta and Gamma in Unity) in degrees. Readings where taken at 0.25 second intervals and compared against the previous point to generate a vector value of each coordinate and rotation, allowing us to judge velocity and changes in movement. These files where then combined into an Excel spreadsheet to filter and process the data as required to generate the scores. We filtered the data and used witness camera footage to get approximate timings for each of the movements measured. We then developed formulae in Excel to produce the scores, and where appropriate averaging the vectors of multiple points on the skeleton together.

Data extracted provided a value of 'difference' (in either direction) for each variable from pre-post testing.

Qualitative data:

Using a framework approach, emergent themes from all transcribed data were generated, working towards a thematic analysis, although appreciation of the limited data size was taken. Framework analysis allows a priori issues and themes to be set. The initial themes for this analysis were determined by initial familiarisation with the data, with reference to the

initial study context and design. All relevant points in each of the transcripts were coded to the initial themes and expanded or collapsed to include or discard sub-themes where appropriate. Data were not forced to fit themes, but as to be expected in such a focussed piece of research, data collected did not necessitate major restructuring of the thematic framework. Any refined sub-themes emerged naturally from initial ones and provided the logical framework to chart the data in an iterative process of coding and framework development. Collating the data in this manner allowed mapping and interpretation, and provided appropriate data for the subsequent stage of this analysis.

Mixed data:

Data were analysed using a 'Convergent Parallel' mixed methods design. This method of analysis makes the following assumptions in reference to the framework proposed by Creswell & Plano Clark [23]. The data sets were mixed at the point of analysis to give a combined interpretation (point of interface).

The purpose of this type of data analysis allows different but complimentary data sets of the same topic, thus bringing together overlapping strengths and weaknesses to gain a greater explorative understanding of the problem and research question posed.

Both qualitative (interview and focus group transcripts) and quantitative data (3-dimensional motion capture) sets were collected concurrently (timing of interaction). There was equal prioritisation of both data sets (priority of interaction) and the data sets were independent during collection (level of interaction).

Mixed data analysis followed the principles of 'Joint categories and themes display', driven by the quantitative analysis.

Qualitative data reporting the immediate physical, or physical and psychosocial effects of dance combined was matched to the specific physical variables of the quantitative data where possible. This enabled a combined analysis of the effect a participant 'felt' dance had physically to be mapped against what was measured/ objectively seen and subjectively seen (by others).

Data that only reported psychosocial effects or long term effects was not included as it is not possible to determine the associate physical variable.

Results were presented descriptively in respect of the explorative nature of the design. This enabled the experience of the dance class to be mapped against any physical change observed (as per research question).

Results

Thirteen participants (6 male, H&Y 1-3) with Parkinson's and 10 carers met the inclusion criteria, each attending one of three, one hour Parkinson's Dance Science classes, held on the same day. All participants had danced for more than 2 years and were independently mobile with or without a walking aid.

Three participants with Hohen and Yahr ratings of 1, and 3 were selected to wear the Mocap Suit. All three were able to wear the suit for the whole class and completed both the pre- and post-recordings of the dance sequence with no adverse effects. All three participants completed the post-class interview and all study participants including carers took part in the post-class focus group discussions.

Quantitative results:

Six movement variables were identified and extracted from the 3-dimensional motion analysis data and differences in the before and after class recordings were identified (Table 2).

Difference between pre- and post-scores were found in all variables for all participants. The greatest differences were found in the velocity of arm movements, the amount of trunk rotation and variables of gait. Minimal changes were seen for all participants in measures of posture and whole-body extension. Two of the three participants showed similar changes in physical parameters and one appeared to be the opposite in most outcomes.

Table 2: Percentage and descriptive change from pre-post scores in each variable for each participant.

Variable	Participant 1	% change	Participant 2	% change	Participant 3	% change
Velocity of arm movement	Faster	47 %	Faster	10%	Slower	33%
Trunk rotation	Smaller	12%	Smaller	14%	Larger	6%
Gait speed	Faster	228%	Faster	0.1%	Slower	10%
Step length	Longer	21%	Longer	23%	Shorter	61%
Posture	More flexed	1%	Straighter	0.2%	Straighter	0.4%
Whole-body extension	Less	5%	More	0.6%	More	2%

Qualitative results

Interview and focus group data were combined. Four overarching themes were identified; Immediate effects, Long term effects, Combined 'mind-body' effects and specific features of the data collection. Combined analysis enabled connections between the movement variables and themes to be made (Table 3).

Immediate effects

All participants discussed the immediate effects of the class in a positive way. When reflecting during the interviews, participants stated functional improvements in specific symptoms, such as balance, walking and rigidity.

> *"This is one of the reasons I take the classes because when I leave…and for these 2 days afterwards my balance feels better" PARTICIPANT 1*

> *"I find that after the class my walking is a lot better – and faster!" PARTICIPANT 1*

After watching the 3-dimensional movement analysis, participants were more specific and critical about the immediate effects with regards to specific symptoms and were able to identify these in others.

> *"His arms are moving freer and he's not shaking as much. I can't understand, his arms seem freer". FOCUS GROUP 1*

> *"Your rotation and everything was much better". FOCUS GROUP 1*

In comparison to these specific effects, participants also talked about the general, more global improvements in their physical abilities immediately after the class.

> *"It generally feels better as you go through the class". FOCUS GROUP 1*

> *"I could see you looked more fluid the second time. It seemed the first one was a bit jerky ...But, it was a definite more fluid movement [the second time]". FOCUS GROUP 3*

As well as immediate physical effects, all participants reported positive psycho-social effects following the class. Impact on specific psychological symptoms such as low confidence, stress, mood and cognitive ability were reported as well as more subjective and emotive effects.

> *"I'm gaining confidence. Yes, it is confidence. I feel confident to do it in class. I'm at my peak if you like (laughs)!" PARTICIPANT 2 in FOCUS GROUP 2*

> *"I feel brighter, more released - I feel apprehensive and tired before the class." FOCUS GROUP 1*

> *"I feel ... less tense leaving the class and more relaxed and more able to cope with life really" PARTICIPANT 3.*

Long term effects:

All participants discussed the long-term impact that the class had on both their physical ability and their wellbeing and quality of life from a psychosocial perspective.

Physically, participants identified the positive effect that the class had on slowing their symptoms and using the class to manage their symptoms on a day to day basis.

> *"But it's 10 or 11 years since I was diagnosed and, it seems to be fairly slow progress. And, I think that might well be down to doing the class". PARTICIPANT 1*

> *"Does someone who does a class once a week, twice a week, three times a week see a bigger difference? Absolutely". FOCUS GROUP 1*

Psychosocially, participants highly valued the social support and friendships they had established through the class, using humour as a means to make connections and a shared understanding.

> *"The mentality I think... we have a lot of fun in the class and there's quite a bit of banter goes on that sort of thing you know. That helps. It takes your mind off the Parkinson's itself". PARTICIPANT 1*

> *"[talking about his tremor] I think it's the old story about being in the same boat as other people. There's a kind of almost a chumminess about it, you know…there's almost an in-built mickey-taking going on... I think it helps people stave it off a little bit. PARTICIPANT 1*

> *"People are much friendlier. Nobody speaks to anyone at the gym". PARTICIPANT 2*

Global combined holistic effects:

All participants gave detailed descriptions of the combined 'mind and body' effects that attending the class had both immediately and over a longer term. This was evident in both the interviews and focus groups.

> *"That's pleasing. It makes you feel better". FOCUS GROUP 1*

> *"Well, yeah, it's a place that my mind and body like to come to". PARTICIPANT 3*

Participants reported the class to have a 'freeing effect' from their condition and improved management of it, offering a feeling and illusion of escapism.

> *"Partially energised, happy in participating, less stressed - Feel more 'on' with my drugs ie movement is freer. Tired mentally… Body more relaxed". PARTICIPANT 2*

> *"I feel lighter, more relaxed, more coordinated, happier, more myself and less 'lock in' to PD. Improved concentration, less anxious. – I feel that it is physically freeing and the emotional and mental changes follow this leaving PD behind. FOCUS GROUP 2*

> *"It makes me feel like I haven't got it. That's the Parkinson's. It makes me feel like what the heck, you know if I want to jump over that gate I will jump over that gate! I mean that's the difference". PARTICIPANT 3*

Specific features of the data collection:
All participants felt the methods of data collection were manageable. All three were able to wear the suit for the whole class and completed both the pre- and post-recordings of the dance sequence with no adverse effects. It was generally felt that the suit did not hinder their dance movement during the class, but one participant felt it was uncomfortable due to the design of the chest strap not being suitable for a female.

Whilst all participants reported positive effects of the class, there were mixed opinions as to if this was a result of one component or technique used in the class having a specific impact on their symptoms or the overall experience of dancing having a global effect.

"Yeah, it's this repetition thing... the more you do it, the better it gets… ". FOCUS GROUP 1

"I think the 'whoosh's', ... or whoa hoo's and the daft sounds and things that we do they make quite a lot of difference". FOCUS GROUP 1

"I don't think you could pick out just one bit and say that's what you've got to do". FOCUS GROUP 1

" I feel a lot of people if they went to a normal [exercise] class, they wouldn't gain much. I think you gain more here [dance class] because... I'm sure you've got an in-built dance...inherent in all of us". PARTICIPANT 3

Mixed method analysis

Table 3, shows the combined analysis of descriptions of 'what was felt' compared to 'what was seen' for each individual.

Table 3: Combined Quantitative and Qualitative data for each participant.

	What you 'SEE'			What I 'FEEL'
	Objective		Subjective	Subjective
	3-dimensional movement variable	Direction of change	Focus group reflection	Participant experience
Participant 1	Velocity of upper limb movements	Faster 47%	His arms are moving freer. And, he's not shaking as much. I can't understand. His arms seem freer.	
	Rotation of the trunk	Smaller (less rotation) 12%	"Your rotation and everything was much better".	"Happier after the class - Freer movement of body core". "Well… that action across the body and the rotation of the trunk area and that sequence of that with switching arms seems to have, made me feel much better".
	Gait analysis (speed)	Faster 228%		"I feel that each time I go to dance class that I come away a bit more mobile". "Better balance means... I find that after the class my walking is a lot better – and faster"!
	Gait analysis (step length)	Longer 21%		"I like the Spanish dance. I think because there are definite movements and striding in one, one direction. Just concentrating on the position of your limbs. I think that felt good".
	Postural alignment (balanced)	Straighter 1%		"My movement is slightly more fluid... Less sleepy, more cheerful, reduction in stiffness. Posture feels better, more open and active". "I find that for 2 days after the class my balance is better. My walking's better. And, I think my posture's better as well. But, it's the psychological feeling that you get. It's almost as if there's something going on in that bit of the brain that isn't working properly. It seems to start flickering. There's almost a feel-good factor, isn't there? That if you

				feel good you release more dopamine! So, it all comes together".
	Whole-body extension	**Less 5%**		
Participant 2	**Velocity of upper limb movements**	**Faster 10%**	"I thought she was slightly quicker in all the movements...a bit freer. She seems to be able to move her arms much better than her legs. …it really caught my eye how much your arm was swinging".	
	Rotation of the trunk	**Smaller 14%**	"I thought she was slightly quicker in all the movements. A bit freer".	"Partially energised, happy in participating, less stressed - Felt more 'on' with my drugs ie movement is freer. Tired mentally. Body more relaxed".
	Gait analysis (speed)	**Faster 0.1%**	"... the crisp movement and you know perhaps we're having an exceptionally good day today [name of respondent] but I've never seen you walk that far and that fast".	"When I'm walking I'm very rigid and it helps me to try and relax and walk more smoothly".
	Gait analysis (step length)	**Longer 23%**	"…. I thought, there was more upper body movement but, actually what I really noticed was, was the transfer of weight onto her legs during stepping"	
	Postural alignment (balance)	**More flexed 0.2%**	"Yeah, you moved a whole lot more there than you do at home...You don't move around the house like that...that's more - the most I've seen you move - or in extremes – you know reaching out and being steady".	"I feel a bit more confident, [the class] addresses issues of balance and coordination and smoothness of movement because my movements are fairly rigid... they make you feel more balanced and more confident and less likely to fall?" "Pleased, interested, bit more upright, or upright".
	Whole-body extension	**More 0.6%**		[why do you come to a weekly class?]"..Because, I think the therapists are very knowledgeable…because I enjoy it… and feel better afterwards. …. I just feel smoother….. Mainly in muscles of movement, you know. Deportment".

Participant 3	**Velocity of upper limb movements**	**Slower 33%**		"I could see you looked more fluid the second time. It seemed the first one was a bit jerky ..." "On the first time…my arms were in the wrong direction...and then I obviously got it together. I was more relaxed. So, the response of that was that it was more fluid". [What does 'fluid' mean?] "I feel relaxed… I'm feeling really yeah, this is great, you know. I can move around and I have hand movement and everything's going well".
	Rotation of the trunk	**More rotation 6%**		"Well, I feel relaxed, I mean if I stay still for too long I get tense and stiff and my movement's restricted to a degree".
	Gait analysis (speed)	**Slower 10%**		"I feel more relaxed-Relaxed – less tense, legs move more easily than before the class or quicker". "I did notice…I sat down for too long when I should be up and walking around. And, then that was relieved as soon as I started".
	Gait analysis (step length)	**Shorter 61%**		
	Posture/balance	**Straighter 0.4%**	"I felt like on the side lean there was more of a weight shift between your feet so, you trusted your body and your balance more the second time because you were willing to transfer your weight over to one side a little bit more".	"I think especially posture…I think it's... really helpful [And, how does the creativity of dance help your posture?]...because if you let your body do what it wants to do you're going downhill…You need it to do what you want it to do. The dance aspect gives me that feeling [of making it do] what I want it to do, not what it wants to do". "I do feel the dance aspect of it is beneficial. It's helped me, I know. I was almost starting to tip over... But, no... It helps…"
	Whole-body extension	**More 2%**		"My breathing got easier...deeper, I think... it made me feel a bit better...Physically [when asked if this was due to any

				part of the class in particular]...Just stretching I think, yes, because I cannot stretch this side at all".

Discussion

This is the first study to uniquely map the immediate experiences of PwP dancing against a specific objective measure of change, or an observed change following a dance for Parkinson's class. It adds novel understanding to the holistic impact of dance for PwP and begins to unpack the potential combined effects across a biopsychosocial model of understanding.

Initial objectives of the study were to determine:

1. Is it feasible to collect measurements of movement in the whole-body in someone with Parkinson's dancing and their experience of the effect of the dance at the same time?
2. Are there any links between what people with Parkinson's say they 'feel' when they dance and what movements can be measured' seen'?

Results indicate that it is feasible to collect whole-body data in PwP dancing using 3-dimensional motion analysis methods and use this to show physical changes in biomechanical measures of movement as a result of participating in a dance class specific for PwP (Objective 1).

The six movement variables were selected based on the hypothesis that the Parkinson's Dance Science model would have an impact on them all at some point in the class, with the pre-post dance sequence being choreographed to enable measurement of all six. Measures of gait (speed and step length), arm velocity and trunk rotation appeared most sensitive to change as a result of dancing in this small sample, whereas measure of posture and whole-body extension did not identify significant change. This is agreement with the current literature showing significant positive effects of dance in PwP for step length and speed [7] as well as clinical measures of mobility [2, 3, 5] and a decrease in trunk rotation [10]. The negligible changes seen in posture also match the lack of significant difference in posture following dance in PwP previously reported in both biomechanical [24] and clinical measures [15]. The lack of previous investigation of arm velocity or whole-body extension following dance in PwP is surprising as this can be clinically justified as a variable of trunk flexibility, the counter symptom of which being trunk rigidity, reported to affect 90-99% of PwP [25]. It is also a variable most likely to be affected by dance considering the whole-body movements adopted.

It was not just the collection of quantitative data in a 'real time' dimension that was important in this study, but also the use of semi-structured interviews with dancers, and focus group reflections and observations from their peers. This qualitative data describes a positive, multi-dimensional effect in the physical, psychological and social context, both short and long term. The unique combination of these data sets enabled 'dancing experiences' to be mapped against 'physical outcomes' to explore the links and effects of both on each other. When mapping the qualitative data, over the quantitative data, all movement variables were discussed at some point, which enabled the linking of experiences and reflections with objective measures of change (Objective 2).

This study was primarily designed to measure the feasibility of conducting an integrated mixed methods analysis, co-collecting both quantitative movement data and qualitative movement experience, the ability of which has been proven. With this small, convenient

sample, further interpretation is developmental, but begins to un-pack the holistic effect of dance for PwP.

Explorative development ideas

Interestingly, the direction of effect for quantitative variables was not the same for all participants, i.e. gait became faster with larger steps for two and slower with smaller steps from one after the class. This was not reflected in the perceived affect or peer observations, with all reporting the effects favourably. Whilst it is not possible to conclude with such a small sample, this does support the suggestion that standardised, fixed outcome measures of the effects of dance for PwP are potentially not measuring the personalised effect for all. As such, traditional means based analysis may be diluted, and reduces the reported effects to one or two pre-selected variables. In support of this, Houston [26] proposes the need to focus on the dancing person, rather than merely on his or her disease, suggesting an understanding of the 'lived experience' is required. The opposing physical effect, but unanimously positive psychosocial effects seen in this study suggests the direction of effect may not be the most important aspect but more the effect of a 'perceived change' that is driving the positive experience. It could be argued that the unique quality of dance allows 'everybody' to experience a new found movement in a positive way, even if the change experienced is in a 'so called' negative direction. Dance may provide an opportunity for movement experimentation and adaption in a personalised way that gives the illusion of improved or greater movement, even if this is not physically the case.

This observation is also seen in the multiple comments on the perception of 'freedom' that dance brings, corresponding with the lack of an objective measure of 'freedom'. This suggests 'freedom' may be a construct of perceived change in movement for each individual, based on their interpretation of the artistic dance movement performed. Further exploration of this concept is required with greater numbers to demonstrate if the 'direction of change' in a biomechanical model or 'perceived change' in a psychosocial model are the driving factors for the lived experience of dance. However, results of this study suggest it is not a straightforward cause and effect relationship.

A similar effect may be found in the variable of posture. Minimal change was shown in all objectively, but all three dancers reported a perceived improvement in their posture. The absence of postural change in previous literature [15, 24], but anecdotal reports of effect (personal conversations) also suggest once again it may be a perception of change that is more important than an actual change or hypothetical improvement in outcome. In addition, the effects of 'better balance' following the class are also widely discussed. 'Better balance' is biomechanically the ability to 'maintain the centre of mass within the base of support' [25], but subjectively the perception of 'ones ability to remain upright'. The effects of dance for PwP on balance has been shown to be multi-dimensional [7] and likely therefore to be a combination of posture, weight shift, perception of movement challenge, speed of movement and reactions to the environment as well as individual internal perceptions. Further mixed methods research should therefore include an objective measure of overall balance to map comments against.

Finally, as well as discussing the positive effects of dance physically, the qualitative data in this study, as with previous literature, strongly suggests a positive effect of dance on social and psychological outcomes [9, 11, 15, 17, 25]. All participants and focus group peer reflections made reference to the importance of community and social interaction through the dance class. It was interesting to note, however, that no causal or direction of effect was

given as to whether the physical changes drive the psychosocial or vis-versa. It appeared psychosocial changes such as being 'happier' or 'enjoyment' were linked to global physical changes such as 'feeling freer' and 'smoother'. Whereas physical objective change was reported more in relation to the specific symptoms of the condition such as 'walking faster', 'feeling better balanced' and 'being more upright'.

Can this be interpreted as, the perception of the physical effects of dance are a result of the personal exploration of movement with 'one's body' in an internal way, whereas social and psychological effects may be a result of the community, relationships and environment of the class in an external way? What effect therefore would dancing alone have on the physical outcomes and perceived effects?

Limitations

The sample size for this study does not enable conclusive understanding of the combined effect of dance for PwP. Suggestions are made for further research purposes only.

The objective measures chosen and extracted were selected based on the expected effect of the Parkinson's Dance Science approach used. Whilst 3-dimensional motion analysis enables large data collection, it is possible that the process of data reduction to the six variables used did not capture all the objective effects of the class. Future research should consider broader, combined measures such as 'balance', 'fluidity' and 'mobility' as a combination of these more discreet variables in order to capture a larger proportion of the data in 'whole-body' approach. Technological developments are likely to also allow a greater level of data synthesis with more sophisticated software, which should be considered at the time of subsequent research design. Combining biomechanical data with clinical measures would also provide understanding of the meaningful clinical effect of dance for PwP in a triangulation approach (biomechanical, clinical and experiential), and enable comparisons to other forms of treatment.

In line with the explorative nature of the study, semi structured interview questions were open and broad. Therefore, much of the data could not be linked to the immediate physical effects (as per research question). Future research should consider the immediate and long-term physical effects to map with the immediate and long term psychosocial effects discussed.

Conclusion

The growth and popularity of dance for PwP may in some way attempt to fill the gap left by conventional exercise, which does not always directly target wellbeing, enjoyment and social participation in a holistic way.

This study demonstrates the unique person-centred effects that dance can offer every individual with Parkinson's in the management of their condition. Some may show preferences to the psychosocial effects, and some the physical, with varying directions of effect (perhaps against the traditional view of a positive improvement towards 'normal'), but what this study shows is for these participants, both are in fact intertwined. Therefore, both cannot be studied in isolation if you are to truly understand the lived, 'mind-body' experience of dance for PwP. This study has proven the feasibility of such measures and in doing so, it is hoped that future work will build on the depth and breadth of understanding enabled.

The growing body of evidence to date has focused on evaluating dance for PwP through its effects on single, isolated variables such as gait, balance, quality of life or disease severity. This study demonstrates the feasibility to move beyond the questions of "does dance work" to understanding "what is it about dance that makes it work for each individual" and demonstrates multiple models are at play in the dancing experience. We must therefore shift away from single variable assessments and arguments of the same effects being experienced by all to complex, mixed methods analysis capable of capturing personalised and unique experiences and effects, to truly un-pack the impact and potential of dance for PwP.

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References:

1. What is Parkinson's [Internet].London: PD UK; 2013- [cited 2013 Feb 24]; Available from: http://www.parkinsons.org.uk/about-parkinsons/what-is-parkinsons.aspx
2. Aguiar LC, Morris ME. Therapeutic dancing for people with Parkinson's disease: A systematic review of its effects on mobility and quality of life. Movement Disorders 2015; 30: S66-S66.
3. Sharp K, Hewitt J. Dance as an intervention for people with Parkinson's disease: A systematic review and meta-analysis. Neuroscience and Biobehavioral Reviews 2014; 47: 445-456.
4. Delabary MD, Komeroski IG, Monteiro EP, Costa RR, Haas AN. Effects of dance practice on functional mobility, motor symptoms and quality of life in people with Parkinson's disease: a systematic review with meta-analysis. Aging Clinical and Experimental Research 2018; 30: 727-735.
5. Lötzke D, Ostermann T, Büssing A. Argentine tango in Parkinson disease—A systematic review and meta-analysis. BMC Neurology 2015; 15.
6. Shanahan J, Morris ME, Bhriain ON, Volpe D, Richardson M, Clifford AM. Is Irish set dancing feasible for people with Parkinson's disease in Ireland? Complementary Therapies In Clinical Practice 2015; 21: 47-51.
7. Sowalsky KL, Sonke J, Altmann LJP, Almeida L, Hass CJ. Biomechanical Analysis of Dance for Parkinson's Disease: A Paradoxical Case Study of Balance and Gait Effects? Explore (New York, N.Y.) 2017; 13: 409-413.
8. Aguiar LPC, da Rocha PA, Morris M. Therapeutic Dancing for Parkinson's Disease. International Journal of Gerontology 2016; 10: 64-70.
9. Mandelbaum R, Lo AC. Examining dance as an intervention in Parkinson's disease: A systematic review. American Journal of Dance Therapy 2014; 36: 160-175.

10. Hulbert S, Ashburn A, Roberts L, Verheyden G. Dance for Parkinson's-The effects on whole body co-ordination during turning around. Complementary Therapies In Medicine 2017; 32: 91-97.
11. Rocha PA, Slade SC, McClelland J, Morris ME. Dance is more than therapy: Qualitative analysis on therapeutic dancing classes for Parkinson's. Complementary Therapies In Medicine 2017; 34: 1-9.
12. Krejcova L, Brito J, Cohen W, Bahia C. Impact of Weekly Dance Classes on Quality of Life of Individuals with Parkinson's Disease. Movement Disorders 2017; 32.
13. Earhart GM. Dance as therapy for individuals with Parkinson disease. European Journal Of Physical And Rehabilitation Medicine 2009; 45: 231-238.
14. Heiberger L, Maurer C, Amtage F, Mendez-Balbuena I, Schulte-Monting J, Hepp-Reymond MC, Kristeva R. Impact of a weekly dance class on the functional mobility and on the quality of life of individuals with Parkinson's disease. Frontiers in Aging Neuroscience 2011; 3.
15. Houston S, McGill A. A mixed-methods study into ballet for people living with Parkinson's. Arts & Health: An International Journal of Research, Policy and Practice 2013; 5: 103-119.
16. Koch S, Kunz T, Lykou S, Cruz R. Effects of dance movement therapy and dance on health-related psychological outcomes: A meta-analysis. The Arts in Psychotherapy 2014; 41: 46-64.
17. McNeely ME, Duncan RP, Earhart GM. Impacts of dance on non-motor symptoms, participation, and quality of life in Parkinson disease and healthy older adults. Maturitas 2015; 82: 336-341.
18. Shanahan J, Morris ME, Bhriain ON, Saunders J, Clifford AM. Dance for People With Parkinson Disease: What Is the Evidence Telling Us? Archives of Physical Medicine & Rehabilitation 2015; 96: 141-153.
19. Lewis C, Annett LE, Davenport S, Hall AA, Lovatt P. Mood changes following social dance sessions in people with Parkinson’s disease. Journal of Health Psychology 2016; 21: 483-492.
20. Foster ER, Golden L, Duncan RP, Earhart GM. Community-based Argentine tango dance program is associated with increased activity participation among individuals with Parkinson's disease. Archives Of Physical Medicine And Rehabilitation 2013; 94: 240-249.
21. Duncan RP, Earhart GM. Randomized controlled trial of community-based dancing to modify disease progression in Parkinson disease. Neurorehabilitation and Neural Repair 2012; 26: 132-143.
22. Hoehn MM, Yahr MD. Parkinsonism: onset, progression and mortality. Neurology 1967; 17: 427-42.
23. Creswell J, Plano Clark V. Designing and Conducting Mixed Methods Research. London, UK: Sage Publications Ltd.; 2017. p.
24. Kunkel D, Fitton C, Roberts L, Pickering RM, Roberts HC, Wiles R, Hulbert S, Robison J, Ashburn A. A randomized controlled feasibility trial exploring partnered ballroom dancing for people with Parkinson’s disease. Clinical Rehabilitation 2017; 31: 1340-1350.
25. Hulbert S, *Dancing with Parkinson's - an exploration of teaching and the impact on whole body coordination when turning.*, in *Faculty of Health Science*. 2015, University of Southampton.
26. Houston S. The Methodological Challenges of Research into Dance for People with Parkinson's. Dance Research 2011; 29: 329-351.